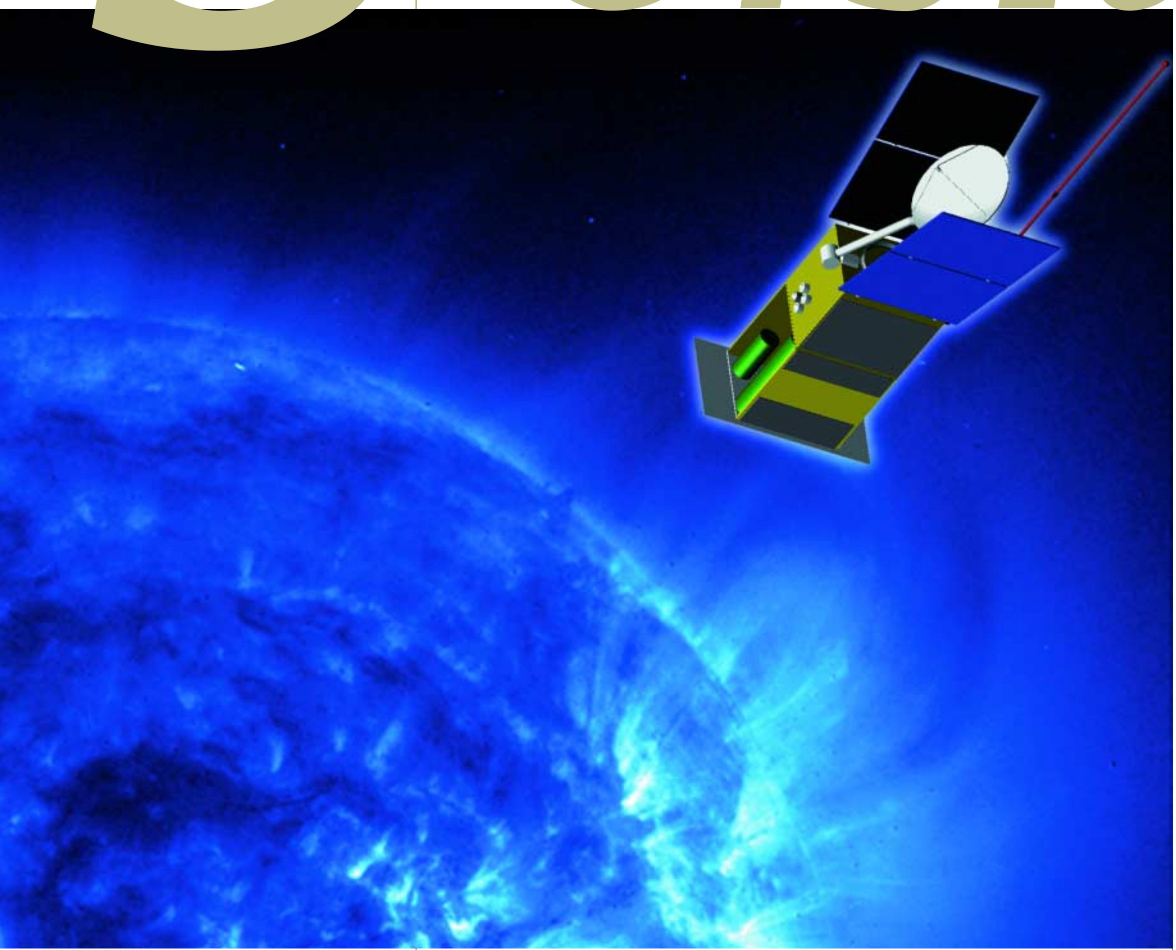
Solar Orbiter

Mission Summary



A high-resolution mission to the Sun and inner heliosphere

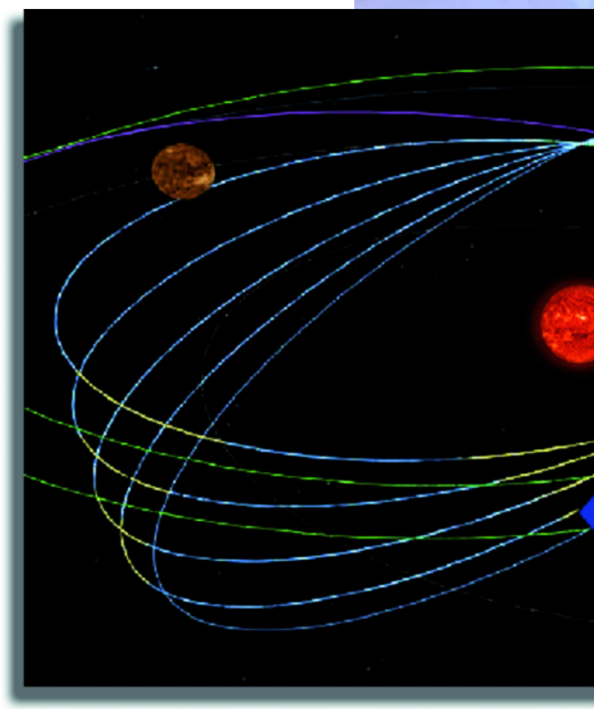
Science in perspective

Solar Orbiter

The Sun's atmosphere and the heliosphere represent uniquely accessible domains of space, where fundamental physical processes common to solar, astrophysical and laboratory plasmas can be studied in detail and under conditions impossible to reproduce on Earth or to study from astronomical distances.

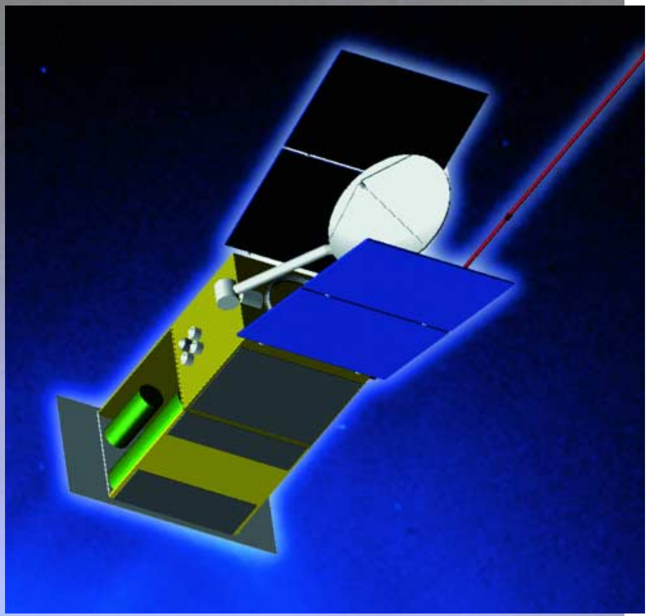
The results from missions such as Helios, Ulysses, Yohkoh, SOHO, and TRACE have enormously advanced our understanding of the solar corona, the associated solar wind and the three-dimensional heliosphere. However, we have reached the point where further in-situ measurements, now much closer to the Sun, together with high-resolution imaging and spectroscopy from a near-Sun and out-of-ecliptic perspective, promise to bring about major breakthroughs in solar and heliospheric physics.

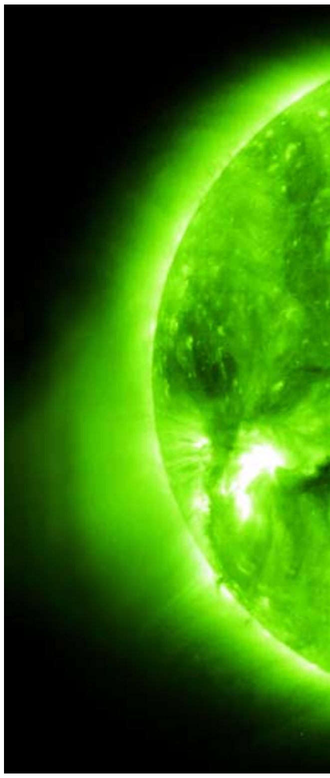
The Solar Orbiter will, through a novel orbital design and its state-of-the-art instruments, provide exactly the observations required.

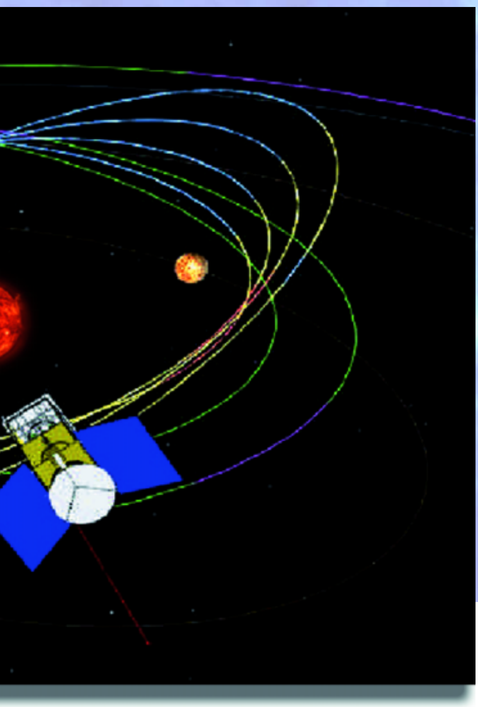


The Solar Orbiter will for the first time:

- explore the uncharted innermost regions of our Solar System
- study the Sun from close-up (45 solar radii, or 0.21 AU)
- fly-by the Sun, tuned to its rotation and examine the solar surface and the space above from a co-rotating vantage point
- provide images of the Sun's polar regions from heliographic latitudes as high as 38 degrees.







The scientific goals of the Solar Orbiter are:

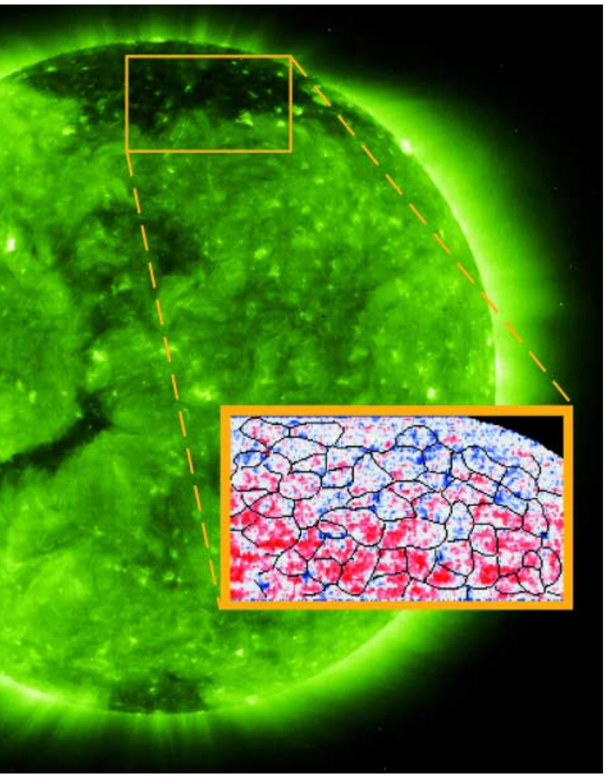
- to determine in-situ the properties and dynamics of plasma, fields and particles in the near-Sun heliosphere
- to investigate the fine-scale structure and dynamics of the Sun’s magnetised atmosphere, using close-up, high-resolution remote sensing
- to identify the links between activity on the Sun's surface and the resulting evolution of the corona and inner heliosphere, using solar co-rotation passes
- to observe and fully characterise the Sun's polar regions and equatorial corona from high latitudes.

The underlying basic questions which are relevant to astrophysics in general are:

- Why does the Sun vary and how does the solar dynamo work?
- What are the fundamental physical processes at work in the solar atmosphere and in the heliosphere?
- What are the links between the magnetic-field-dominated regime in the solar corona and the particle-dominated regime in the heliosphere?

In particular, we want:

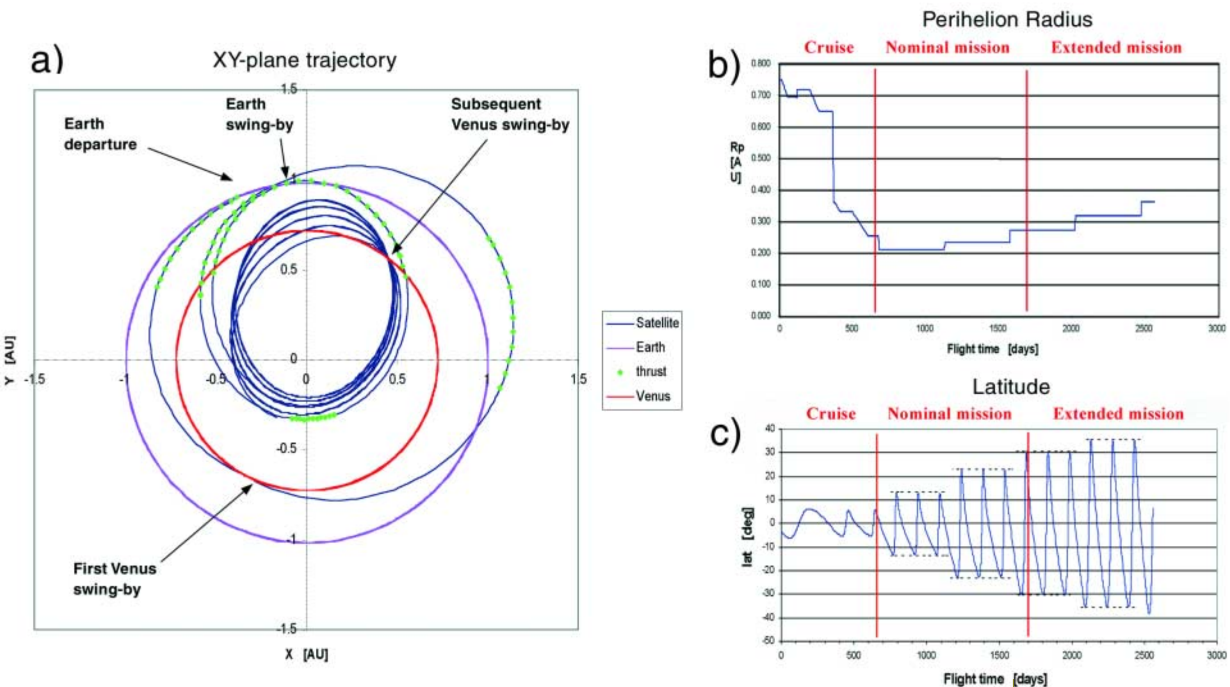
- to unravel the detailed working of the solar magnetic field as a key to understanding stellar magnetism and variability
- to map and describe the rotation, meridional flows, and magnetic topology near the Sun's poles, in order to understand the solar dynamo
- to investigate the variability of the solar radiation from the far side of the Sun and over the poles
- to reveal the flow of energy through the coupled layers of the solar atmosphere, e.g. to identify the small-scale sources of coronal heating and solar-wind acceleration



SOHO observations of the solar-wind source regions, which illustrate the need for high-latitude observations and the potential for linking remote-sensing and in-situ measurements of surface and solar-wind structure and activity. The green image shows the extreme UV Sun (SOHO/EIT) with the polar coronal holes clearly visible. SOHO/SUMER Doppler images (Neon VIII) show blue- and red-shifted flows; black lanes indicate the supergranular network boundaries. The wind outflows (blue shifts) clearly originate in the network cell boundaries and junctions. This is an intriguing result, but Doppler shifts cannot be measured in the plane of the sky; a thorough understanding of the polar outflow of the high-speed solar wind cannot be achieved without Doppler imaging from well out of the ecliptic plane. In addition, the distribution of the solar-wind outflow regions, which is determined by the network, should result in an imprint on the solar-wind flow pattern, which can be confirmed using in-situ measurements.

- to analyse fluctuations and wave-particle interactions in the solar wind, in order to understand the fundamental processes related to turbulence at all relevant scales in a tenuous magnetofluid
- to understand the Sun as a prolific and variable particle accelerator
- to study the nature and the global dynamics of solar eruptive events (flares, coronal mass ejections, etc.) and their effects on the heliosphere ("space weather and space climate").

The near-Sun interplanetary measurements together with simultaneous remote-sensing observations of the Sun will permit us to disentangle spatial and temporal variations during the co-rotational phases. They will allow us to understand the characteristics of the solar wind and energetic particles in close linkage with the plasma conditions in their source regions on the Sun. By approaching as close as 45 solar radii, the Solar Orbiter will view the solar atmosphere with unprecedented spatial resolution (35 km pixel size, equivalent to 0.05 arcsec from Earth). Over extended periods the Solar Orbiter will deliver images and data from the polar regions and the side of the Sun not visible from Earth.



a) Ecliptic projection of the Solar Orbiter trajectory. Blue: Solar Orbiter. Pink: Earth orbit. Red: Venus orbit. Green: SEP Thruster firings.
b) Perihelion distance of the Solar Orbiter as a function of time.
c) Spacecraft latitude with respect to the Sun's equator as a function of time.

The Solar Orbiter will achieve its wide-ranging aims with a suite of sophisticated instruments. Due to the Orbiter's proximity to the Sun, the instruments can be fairly small compared to instrumentation required at the Earth's orbit.

The payload includes two instrument packages, optimised to meet the solar and heliospheric science objectives:

- Heliospheric *in-situ* instruments: solar wind plasma analyser, radio and plasma wave analyser, magnetometer, energetic particle detectors, interplanetary dust detector, neutral particle detector, solar neutron detector.
- Solar remote-sensing instruments: EUV full-Sun and high resolution imager, high-resolution EUV spectrometer, high-resolution visible-light telescope and magnetograph, EUV and visible-light coronagraph, radiometer.

Mission Concept	View the Sun from near-Sun and out-of-ecliptic perspectives and perform · spectroscopy and imaging at high resolution · co-rotational in-situ sampling of particles and fields · remote-sensing of the polar regions of the Sun
Payload	Mass: 130 kg Power: 125 W Telemetry: 75 kb/s Heliospheric instrumentation: · Solar Wind Plasma Analyser · Radio and Plasma Wave Analyser · Magnetometer · Energetic Particle Detector · Neutral Particle Detector · Dust Detector · Neutron Detector · Coronal Radio Sounding Solar remote-sensing instrumentation: · Visible-Light Imager and Magnetograph · EUV Spectrometer · EUV Imager · Ultraviolet and Visible-Light Coronagraph · Radiometer
Spacecraft	· Design lifetime = 5 years · Consumables sized for 7 years · Total mass = 1308 kg · Dimensions: 3 m x 1.2 m x 1.6 m · 3-axis stabilised, Sun-pointing · Pointing stability better than 3 arcsec/15 min · Solar electric propulsion system: 4 x 0.15 N plasma thrusters · Cruise solar arrays (28 m^2) jettisoned after last SEP thrusting · Orbit solar arrays (10 m^2): tiltable · X-band low-gain antennae, omni coverage · Ka-band high-gain antenna, 1.5 m diameter
Launcher	Dedicated launch with Soyuz-LV Fregat from Baikonur.

The Solar Orbiter spacecraft benefits from technology developed for the Mercury Cornerstone mission. This allows such an ambitious mission to be carried out within the frame of an F mission.

Using Solar Electric Propulsion (SEP) in conjunction with multiple planetary swing-by manoeuvres, it will take the Solar Orbiter only two years to reach a perihelion of 45 solar radii with an orbital period of 149 days. Within the nominal 5 year mission phase, the Solar Orbiter will perform several swing-by manoeuvres at Venus, in order to increase the inclination of the orbital plane to 30° with respect to the solar equator. During an extended mission phase of about two years, the inclination will be further increased to 38°.

The spacecraft will be 3-axis stabilised and always Sun-pointed. Given the extreme thermal conditions at 45 solar radii (25 solar constants), the thermal design of the spacecraft has been considered in detail during the assessment study and viable solutions have been identified. Telemetry will be handled via X-band low-gain antennae, and by a 2-axis steerable Ka-band high-gain antenna.

The total mass of the Solar Orbiter is compatible with a Soyuz-Fregat launch from Baikonur.